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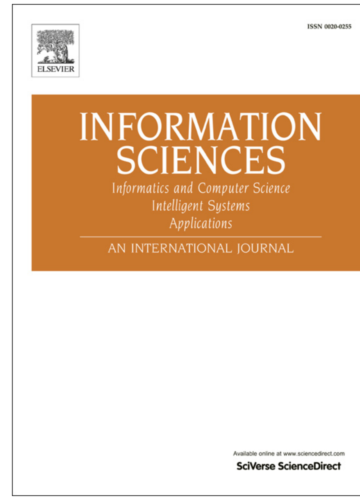

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Zhi Liu, Ci Chen, Yun Zhang, C.L. Philip Chen

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Coordinated Fuzzy Control of Robotic Arms with Actuator Nonlinearities and Motion Constraints

Zhi Liu, Ci Chen, Yun Zhang, and C. L. Philip Chen

Abstract

In this paper, a coordinated fuzzy control is developed for robotic arms with actuator hysteresis and motion constraint. To accurately compensate the hysteresis phenomena from the electromechanical devices, the modelling of actuator hysteresis is first integrated into the dynamics of multiple arms system. Then, the adaptive control scheme is introduced to reduce the harmful effects from unknown nonlinearities. Subsequently, the issue of the motion constraint is taken into account to facilitate the application in the condition of potential collisions. Furthermore, the stability analysis is carried out to guarantees the motion and internal forces in the robotic arms converge to the desired values. Simultaneously, the predetermined motion boundary is ensured to be never violated. Finally, comparative results are presented to illustrate the proposed scheme's effectiveness.

Index Terms

Multiple arms, motion/force, actuator hysteresis, motion constraint, adaptive fuzzy control.

I. Introduction

Recently, researchers have shown an increased attention in the multiple robotic arms system for both industrial and domestic applications [2], [21], [24], [44], [50], [55]. In the industrial applications, such robotic system can provide the labor support with high productivity, which is potential of reducing the cost. For the domestic missions, as the demand for the robots in health care and household environments increases, so does the need for accomplishing the dextrous tasks [44], [55], [56]. However, above-mentioned versatilities of multiple arms are acquired at the expense of the added motion/force complexities.

To tackle such coupled control problem, the motion/force hybrid control schemes have been successfully developed by [3], [9], [28], [43]. However, since the modeling imperfection is inevitable in the real world applications, the effectiveness of those methods for the multiple arms is usually limited. To remove the limitation, an extension from conventional adaptive control to adaptive soft computing and optimized adaptive control has been realized by [1], [4], [7], [10], [14]–[16], [26], [32]–[34], [36], [37], [52], [57], [58]. Furthermore, some efforts have been recently paid to apply adaptive soft computing into the multiple arms manipulation. Gueaieb *et al.* [13] proposed a robust hybrid intelligent control technique for the cooperative manipulators. Li *et al.* [23] developed an adaptive fuzzy logic system based control for the multiple mobile manipulators system with non-rigid environments. Li *et al.* [22] successfully constructed a fuzzy control approach to tackle the multilateral teleoperation with stochastic communication delays. Even though many progresses have been achieved, there has been little discussion about control difficulties from the actuator nonlinearities and motion constraints, which prevent the multiple robots from further prompting the coordinated performances.

It is noted that the actuator dynamics is an essential component of system dynamics, whereas actuator nonlinearities are the common phenomena in the applications [29]–[31], [38], [42], [47], [54], [63]. Due to the existence of ferromagnetic materials in the motors, the hysteresis characteristic is inevitably imposed such that the hysteresis phenomena are supposed to be introduced into the actuator dynamics. Hence, nonlinearities may accompany as long as actuators operate. Moreover, the robotic system preceded by the actuator hysteresis can not be successfully controlled by conventional algorithms based on the ideal actuator's linear property [60]. To deal with the hysteresis nonlinearity, several approaches have been recently proposed which may be classified into two categories: (1) A hysteresis inverse is constructed to compensate the effects of unknown hysteresis effect [18], [45], [59], [62]; (2) The nonlinearity of hysteresis is decomposed into the component multiplying the input control and the uncertain parameters of the system and a bounded disturbance component [40], [46], [51], [61]. It is noted that researches so far on multiple arms have ignored the actuator hysteresis in the field of multiple arms. However, such existing nonlinearity degrades the system's motion/force performances and limits the improvement. Therefore, it remains a challenging task to guarantee the high quality motion/force performances when the multiple arms are performed with unknown actuator hysteresis.

Another challenging problem in the practical application is to avoid the collisions between the manipulated object and other robots or the nearby surroundings [43]. It is thus required that the operating workplace should have a predefined region in terms of size, shape and orientation. Recently, the idea of Barrier Lyapunov Function (BLF) has been successfully developed for control of some kinds of nonlinear systems with output and state constraints [39], [41], [48], [49]. However, most recent

Corresponding author: Z. Liu.

Z. Liu, C. Chen and Y. Zhang are with School of Automation, Guangdong University of Technology, Guangzhou, Guangdong, China. C. L. P. Chen is with Faculty of Science and Technology, University of Macau, Macau, China. E-mail address: lz@gdut.edu.cn.; gdutcc@gmail.com; yz@gdut.edu.cn; philip.chen@ieee.org.

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